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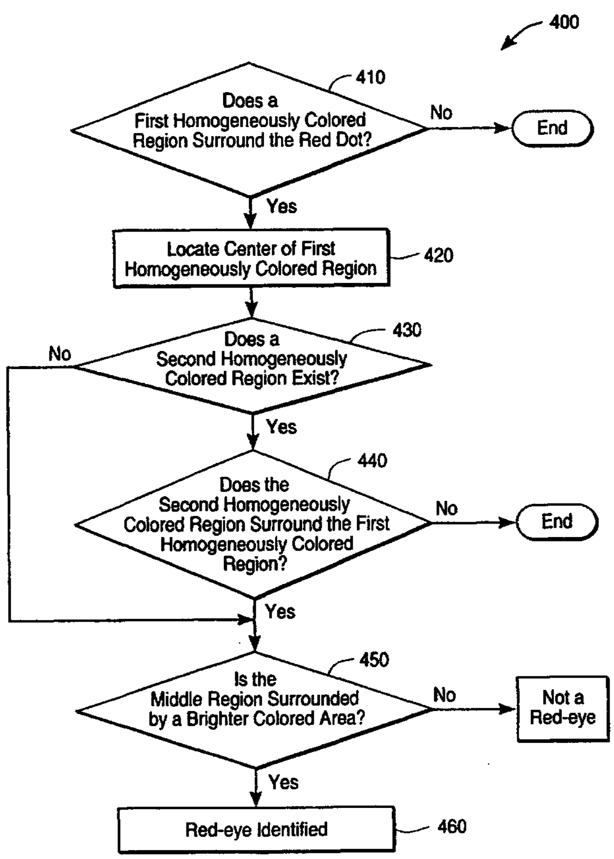
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: RED-EYE CORRECTION BY IMAGE PROCESSING



(57) Abstract: A computer implemented method, system, and computer-readable medium for identifying and correcting red-eyes in images. The method includes the acts of determining the presence of at least one homogeneously colored region (620); determining whether an eye image surrounds the at least one homogeneously colored circular region (630, 410, 420, 430, 440, 450); and replacing the color of the at least single colored circular region with the color of a region that immediately surrounds the at least one homogeneously colored circular region (640).

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RED-EYE CORRECTION BY IMAGE PROCESSING

1. Field of the Invention

This invention pertains to the field of image processing, and more particularly to the field of correction of red-eyes in images.

2. Description of Background Art

In flash photography, the "red-eye effect" is a well known problem. The "red-eye effect" is at least one red dot appearing in the pupil of an eye image. One conventional technique to reduce the red-eye effect is to use a pre-flash light emission technique. In the pre-flash light emission technique, when a shutter release button is pressed, a pre-flash is fired. When the pre-flash strikes a subject's eyes, the pupils of the subject's eyes shrink in response to the bright light. Subsequently, within a short time, the primary flash fires before the pupils revert to normal size. Thereby, the red dots of the pupils are reduced due to the smaller size of the pupils. For a description of a suitable pre-flash light emission technique, see for example, U.S. Patent 4,285,588 to Kodak.

One drawback to the pre-flash light emission technique is the picture taken is not that desired because of a time delay between the desired shutter release time and the time of actual shutter release. Another drawback to the pre-flash light emission technique is the pre-flash distorts the intended picture by, for example, shrinking the

subject's pupils. Still another drawback to the pre-flash light emission technique is when the subject is not looking at the camera, the subject's eyes do not react to the pre-flash, and conventional technique does not prevent red-eye.

Thus what is needed is an apparatus and method that eliminates the red-eye effect but does not distort the subject image.

Disclosure of Invention

The present invention includes a computer implemented method for identifying and correcting red-eyes. The method includes the acts of determining the presence of a red colored region (620); determining whether an eye image surrounds the red colored region (410, 420, 430, 440, 450, and 630); and replacing the color of the red colored region with a color of a region that immediately surrounds the red colored region (510, 520, 530, and 640).

The present invention further includes a computer system (100) adapted for locating and modifying a red-eye in a first image, the system including: a storage medium (102) for storing the first image (110) that includes a red dot and at least one eye image; a red dot detector (104) coupled to the storage medium for receiving the first image from the storage medium and for detecting the presence of the red dot within the first image and for identifying the red dot; an eye detector (106) coupled to the red dot detector for receiving the identified red dot from the red dot detector (104) and for determining whether the red dot is positioned within an eye image and for outputting the location of the red dot positioned within the eye image; and a red-eye remover (108) coupled to the eye detector for receiving the location of the red dot positioned within the

eye image and for replacing the color of the red dot positioned within the eye image with the color of the region that immediately surrounds the red dot.

Brief Description of the Drawings

These and other more detailed and specific objects and features of the present invention are more fully disclosed in the following specification, reference being had to the accompanying drawings, in which:

FIG. 1A depicts in block diagram form an exemplary embodiment of red-eye correction device 100;

FIG. 1B depicts in block diagram form an exemplary embodiment of eye detector 106 of red-eye correction device 100;

FIG. 1C depicts in block diagram form an exemplary embodiment of red-eye remover 108 of red-eye correction device 100;

FIG. 2 depicts an exemplary image 110 having multiple red dots 202-1 to 202-5;

FIG. 3A depicts a suitable process 300 to identify red dots;

FIG. 3B depicts a suitable process to determine whether a red area is circular;

FIG. 4 depicts a suitable process 400 to determine whether a red dot is spatially enclosed within an eye image;

FIG. 5 depicts a suitable process 500, in accordance with an embodiment of the present invention; and

FIG. 6 depicts a suitable process 600, in accordance with an embodiment of the present invention.

Detailed Description of the Preferred Embodiments

Embodiments of the present invention can be used in conjunction with any image recording device, such as a camera (e.g., digital or non-digital), or in an environment that processes still images (e.g., photo development minilabs or internet based photo processing services). Additionally, embodiments of the present invention can be used in conjunction with any video recording device, as video may be a series of still images.

In accordance with embodiments of the present invention, at least an apparatus and process are disclosed herein that locate a red dot within an eye image and replace the red dot with the color of the pupil or iris that encapsulates the red dot. Hereafter "red-eye" means a red dot located within an eye image. Thereby, the red-eye effect is corrected without need for an image distorting pre-flash.

FIG. 1A depicts in block diagram form an exemplary embodiment of red-eye correction device 100. Red-eye correction device 100 can be implemented in hardware, software, and/or firmware. Red-eye correction device 100 includes a storage medium 102, red dot detector device 104, eye detector 106, and red-eye remover 108.

Suitable implementations of storage medium 102 are a random access memory (RAM), magnetic or optical storage medium, or allocated memory space. For example, when the red-eye correction device 100 is used in conjunction with a camera, an exemplary storage medium 102 is a flash memory such as the Iomega Click or the IBM microdisk. Storage medium 102 stores an image 110, which, in this embodiment, is represented in conventional red-green-blue (RGB) format. In this example, the image 110 represents a still image that includes at least one red-eye. Herein, image 110 is

also an image represented by the image 110 unless otherwise stated. FIG. 2 depicts an example image 200, represented by the image 110, that includes multiple red dots 202-1 to 202-5.

The storage medium 102 is coupled to provide the image 110 to red dot detector device 104. Red dot detector device 104 detects all red colored approximately circular shaped regions ("red dots") in image 110. An exemplary approach to identify red dots in image 110 is provided as process 300 of FIG. 3A.

In action 310 of process 300, an area A having N red pixels is identified by using a classical component algorithm whereby all pixels of area A, {(x1,y1), (x2,y2), ..., (xn,yn)}, such that each pixel (xi,yi) is an "8-neighbor" of at least another pixel (xj,yj) of area A. Two pixels (xi,yi) and (xj,yj) are "8-neighbors" if |xi-xj|<=1 and |yi-yj|<=1. The area A is built by starting from a red pixel (x1,y1) and using a classical connected component algorithm to build the area A which contains (x1,y1).

In action 320, the red dot detector device 104 determines if the shape of the area A of red pixels is circular. One suitable technique to determine whether the area A is circular is shown in FIG. 3B.

In action 320-1 of FIG. 3B, red dot detector device 104 determines the centroid (xg, yg) of area A using a conventional calculation such as:

xg = 1/N * (x1+x2+...+xN) and

yg = 1/N * (y1+y2+...+yN).

In action 320-2, red dot detector device 104 encloses the area A with bounding box B to determine the compacity C and excentricity E of the area A. The compacity C of area A is defined as the ratio of the number of pixels N and the

area of the bounding box B, areaB, as further defined in the following equation:

$C = N/areaB$,

where $areaB = H*L$,

where

$H = yr-yl+1$,

$L = xr-xl+1$,

where

(xl, yl) are the upper left hand coordinates of the bounding box B and are obtained by $xl = \min(x1,x2 \ldots xN)$ and $yl = \min(y1,y2 \ldots yN)$; and

(xr, yr) are the lower right hand coordinates of the bounding box B and are obtained by $xr = \max(x1,x2 \ldots xN)$ and $yr = \max(y1,y2 \ldots yN)$;

The excentricity E of the area A is defined as the ratio of the short side of bounding box B with the ratio of the long side of bounding box B. The following equation defines the excentricity E:

$E = \min(H,L)/\max(H,L)$.

In action 320-3, the red dot detector device 104 uses the compacity C and excentricity E to determine if the area A is circular. In this embodiment, if any of the following conditions are true, area A is circular:

i. (N < minpixel) OR

ii. (N > minpixel) and (N < maxpixel) and (C > mincompact) and (E > minexcentricity)

where

minpixel is a threshold under which the area A is too small and therefore is accepted as red dot. A typical value of minpixel is 20;

maxpixel is a threshold above which the area A is rejected as red dot because it is too big. For example, maxpixel can be fixed to the quarter or full size of the image;

mincompact is a threshold under which the area A is rejected because it is too compact. Setting mincompact to 0 cancels this test. Setting mincompact to 1.0 makes the red dot detector device 104 very selective about the compacity; and

minexcentricity is a threshold under which the area A is rejected because it is too elongated. Setting minexcentricity to 0 cancels this test. Setting minexcentricity to 1.0 makes the red dot detector device 104 very selective about the excentricy.

For a 10 cm by 14.9 cm photograph that includes one or several persons, typically, minpixel = 40, maxpixel = 1000, mincompact = 0.3, and minexcentricity = 0.3.

The red dot detector device 104 then identifies all red dots in image 110 to the eye detector 106. An exemplary manner to identify each red dot is to identify the coordinates of each pixel within a red dot, as well as the following proprerties of the red dot: 1) compacity C, 2) excentricity E, 3) centroid (xg, yg), and 4) radius rd of the minimum circle which englobes the red dot. The radius rd is the largest distance linking the centroid (xg,yg) to each point (xi,yi) within the red dot and is further defined in the following equation:

rd = max(d((xg,yg),(xi,yi))), I = 1 to N

where the function d() is the euclidean distance between two points.

Thus with respect to the example of FIG. 2, red dot detector device 104 identifies red dots 202-1 to 202-5 to eye detector 106.

Eye detector 106 detects whether each red dot identified by the red dot detector device 104 is spatially enclosed within an eye image. One suitable approach performed by eye detector 106 to determine whether a red dot is spatially enclosed within an eye image is described with respect to process 400 of FIG. 4. Process 400 is repeated for each red dot.

In action 410 of process 400, the eye detector 106 extends a ray from the centroid (xg, yg) to determine whether a first homogeneously colored circular region encapsulates the red dot. In one embodiment, the first homogeneously colored circular region corresponds to the pupil. For example, referring to the image 200 of FIG. 2, region 220 corresponds to a first homogeneously colored circular region. If a first homogeneously colored circular region encapsulates the red dot, then in action 420, the eye detector 106 locates the center of the first homogeneously colored circular region (x*, y*). For example, referring to the image 200 of FIG. 2, point 225 corresponds to the center of the first homogeneously colored circular region. Otherwise, the eye detector 106 determines that the red dot is not a "red-eye".

In action 430, the eye detector 106 determines whether to locate a second homogeneously colored circular region. In this embodiment, the eye detector 106 locates a second homogeneously colored circular region by examining the size of the red dot. If the size of the red dot is sufficiently small, the eye detector 106 presumes that the first homogeneously colored circular region does not correspond

to a pupil image because the pupil will not be resolved. The eye detector 106 identifies the first homogeneously colored circular region as an iris and proceeds to action 450. Otherwise, if the size of the red dot is sufficiently large such as in the example of FIG. 2, the eye detector 106 identifies the first homogeneously colored circular region as a pupil and proceeds to action 440.

In action 440, the eye detector 106 seeks a second homogeneously colored circular region by extending a second ray from the center (x*, y*) of the first homogeneously colored circular region. The second homogeneously colored circular region corresponds to an iris. For example, referring to the image 200 of FIG. 2, region 230 corresponds to a second homogeneously colored circular region. If such second homogeneously colored circular region is located, then action 450 follows.

In action 450, the eye detector 106 extends the second ray from the center (x*, y*) of the first homogeneously colored circular region or from the edge of the first homogeneously colored circular region (action 440) to locate a region that is brighter than the homogeneously colored region outmost from the red dot (e.g., first homogeneously colored circular region or second homogeneously colored circular region) ("middle region"). The brighter region corresponds to the sclera. For example, referring to the image 200 of FIG. 2, region 240 corresponds to the brighter region. If the region that surrounds the middle region is brighter than the middle region, then in action 460, eye detector 106 identifies the red dot as a "red-eye".

Otherwise, if the region that surrounds the middle region is not brighter than the middle region, then eye

detector 106 determines that the red dot is not a "red-eye".

FIG. 1B depicts in block diagram form an exemplary embodiment of eye detector 106 of red-eye correction device 100. Eye detector 106 includes first homogeneous region detector 152 that performs the actions 410, 420, and 430 of process 400; second homogeneous region detector 154 that performs action 440 of process 400; and brightness detector 156 that performs action 450 of process 400.

Numerous alternatives to process 400 are available. For example, one alternative to process 400 is described in U.S. Patent No. 5,164,992 to Massachusetts Institute of Technology, which is incorporated by reference herein in its entirety.

After repeating process 400 for all red dots within image 110, the eye detector 106 identifies all red-eyes within the image 110 to the red-eye remover 108. A suitable manner that eye detector 106 identifies red-eyes to the red-eye remover 108 is by providing: 1) the coordinates of each pixel within a red-eye, 2) the center coordinates (x^*, y^*) of the first homogeneously colored circular region (e.g., pupil or an iris), and 3) a ray r^* defining the radius of the first homogeneously colored circular region. The red-eye remover 108 further receives the image 110 from the storage medium 102.

FIG. 5 depicts a suitable process 500 performed by the red-eye remover 108 for correcting the color of each red-eye. In action 510 of process 500, the red-eye remover 108 determines the color of the first homogeneously colored circular region (i.e., pupil or iris). One suitable technique to determine the color of the first homogeneously colored circular region that surrounds a red-eye is as

follows. The red-eye remover 108 determines the mean color of all pixels within the first homogeneously colored circular region. In this embodiment, the mean color is determined in terms of colors red, green, and blue (RGB). In action 520, the red-eye remover 108 replaces the red, green, and blue color components of the red-eye in image 110 with the respective mean red, green, and blue colors of the first homogeneously colored circular region. Hereafter "modified image" means the image 110 having the red-eyes modified by action 520. In action 530, the red-eye remover 108 stores the modified version of image 110 to the storage medium 102.

FIG. 1C depicts in block diagram form an exemplary embodiment of red-eye remover 108 of red-eye correction device 100. Red-eye remover 108 includes a color detector 170 that performs action 510 of process 500; and color replacer 172 that performs actions 520 and 530 of process 500.

Suitable process

Accordingly, a suitable process in accordance with an embodiment of the present invention is represented in FIG. 6 as process 600. In action 610 of process 600, a digital image 110 is available in RGB format. In action 620, red dots within the digital image are detected and identified. In action 630, each red dot is examined to determine whether it is a red-eye. An exemplary action 630 is process 400 or its alternate described earlier. In action 640, the color of each red-eye in image 110 is replaced with the mean color of the first homogeneously colored circular region (i.e., iris or pupil). An exemplary action 640 is process 500 described earlier.

Modifications

The above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. For example, non-red colored-eye image distortions can be modified. The scope of the invention is to be limited only by the following claims. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the spirit and scope of the present invention.

What is claimed is:

Claims

1. A computer-implemented method for identifying and repairing red-eyes, the method comprising the steps of:

determining the presence of a red colored region;

determining whether an eye image surrounds the red colored region; and

replacing the color of the red colored region with a color of a region that immediately surrounds the red colored region.

2. The method of Claim 1, wherein the step of determining whether an eye image surrounds the red colored region comprises the substeps of:

determining whether a first homogeneously colored region surrounds the red colored region;

determining whether a second homogeneously colored region surrounds the first homogeneously colored region; and

determining whether a region brighter than the second homogeneously colored region surrounds the second homogeneously colored region.

3. The method of Claim 2, wherein the step of replacing comprises the substeps of:

determining the color of the first homogeneously colored region; and

replacing the color of the red colored region with the color of the first homogeneously colored region.

4. The method of Claim 2, wherein the step of determining whether a first homogeneously colored region surrounds the red colored region comprises the substeps of:

determining a center of the red colored region; and

extending at least one ray from the center to determine whether the first homogeneously colored region surrounds the red colored region.

5. The method of Claim 2, wherein the step of determining whether a second homogeneously colored region surrounds the first homogeneously colored region comprises the substeps of:

determining a center of the first homogeneously colored region; and

extending at least one ray from the center of the first homogeneously colored region to determine whether the second homogeneously colored region surrounds the first homogeneously colored region.

6. The method of Claim 5, further comprising:

extending at least one ray from the center of the first homogeneously colored region to determine whether a region brighter than the second homogeneously colored region surrounds the second homogeneously colored region.

7. The method of Claim 1, wherein the red colored region is circularly shaped.

8. The method of Claim 1, wherein the step of determining whether an eye image surrounds the red colored region comprises the substeps of:

determining whether a first homogeneously colored region surrounds the red colored region; and

determining whether a region brighter than the first homogeneously colored region surrounds the first homogeneously colored region.

9. The method of Claim 8, wherein the step of determining whether a first homogeneously colored region surrounds the red colored region comprises the substeps of:

determining a center of the red colored region; and

extending at least one ray from the center to determine whether the first homogeneously colored region surrounds the red colored region.

10. A computer-implemented method for diagnosing and repairing red-eyes in an image, the method comprising the steps of:

determining the presence of a red colored region;

determining whether a first homogeneously colored region surrounds the red colored region;

determining whether a region brighter than the first homogeneously colored region surrounds the first homogeneously colored region;

determining the color of the first homogeneously colored region; and

replacing the color of the red colored region with the color of the first homogeneously colored region.

11. The method of Claim 10, wherein the red colored region is circularly shaped.

12. The method of Claim 10, wherein the first homogeneously colored region is an iris image.

13. The method of Claim 10, wherein the region brighter than the first homogeneously colored region is a sclera image.

14. A computer system adapted for locating and modifying a red-eye in a first image, the system comprising:

a storage medium for storing the first image that includes a red dot and at least one eye image;

a red dot detector coupled to the storage medium for receiving the first image from the storage medium and for detecting the presence of the red dot within the first image and for identifying the red dot;

an eye detector coupled to the red dot detector for receiving the identified red dot from the red dot detector and for determining whether the red dot is positioned within an eye image and for outputting the location of the red dot positioned within the eye image; and

a red-eye remover coupled to the eye detector for receiving the location of the red dot positioned within the eye image and for replacing the color of the red dot positioned within the eye image with the color of the region that immediately surrounds the red dot.

15. The computer system of Claim 14 wherein the eye detector comprises:

a module for determining whether a first homogeneously colored region surrounds the red dot; and

a module for determining whether a region brighter than the first homogeneously colored region surrounds the first homogeneously colored region.

16. The computer system of Claim 15 wherein the red-eye remover comprises:

a module for determining the color of the first homogeneously colored region; and

a module for replacing the color of the red dot with the color of the first homogeneously colored region.

17. The computer system of Claim 14 wherein the eye detector comprises:

a module for determining whether a first homogeneously colored region surrounds the red dot;

a module for determining whether a second homogeneously colored region surrounds the first homogeneously colored region; and

a module for determining whether a region brighter than the second homogeneously colored region surrounds the second homogeneously colored region.

18. The computer system of Claim 17 wherein the red-eye remover comprises:

a module for determining the color of the first homogeneously colored region; and

a module for replacing the color of the red dot with the color of the first homogeneously colored region.

19. A computer-readable medium that locates and modifies a red-eye in an image, the computer-readable medium comprising:

an image including a red dot;

a code segment for determining whether a first homogeneously colored region surrounds the red dot;

a code segment for determining whether a region brighter than the first homogeneously colored region surrounds the first homogeneously colored region;

a code segment for determining the color of the first homogeneously colored region; and

a code segment for replacing the color of the at least one red dot with the color of the first homogeneously colored region.

DRAWINGS

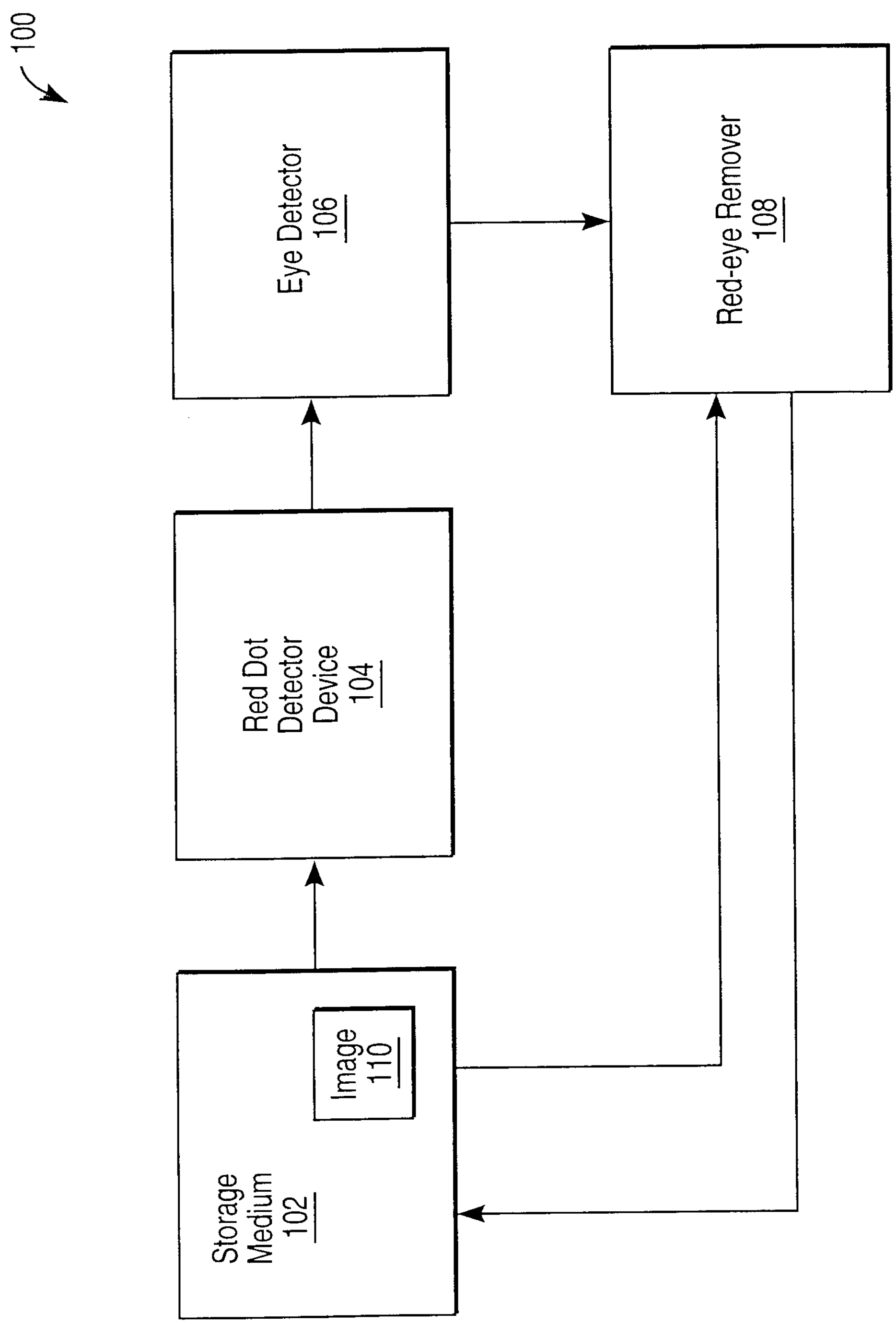

FIG. 1A

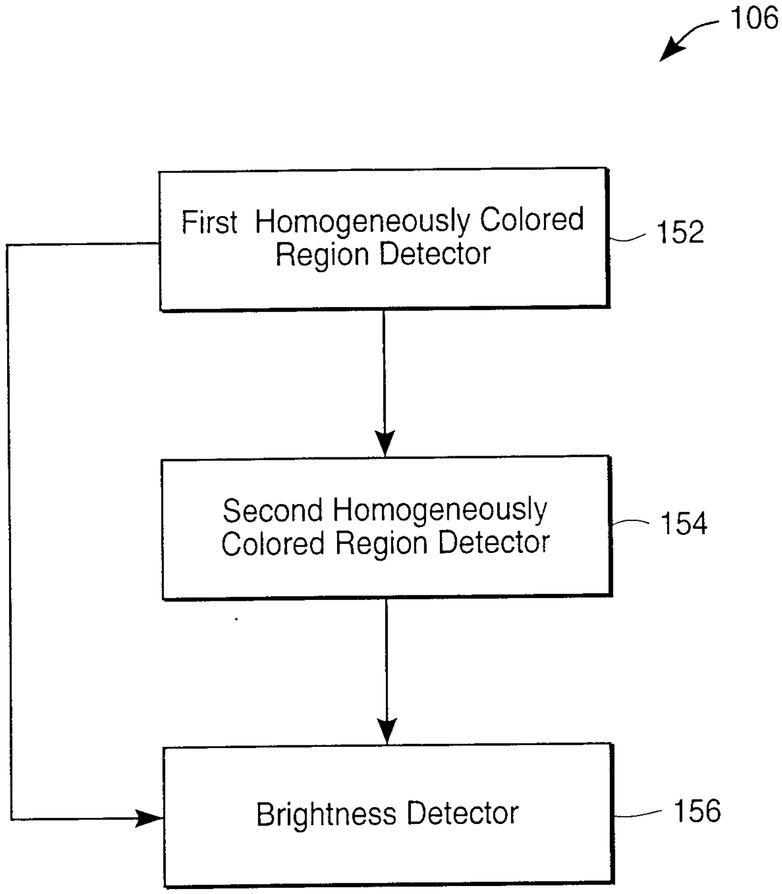
106
First Homogeneously Colored Region Detector
152
Second Homogeneously Colored Region Detector
154
Brightness Detector
156

FIG. 1B

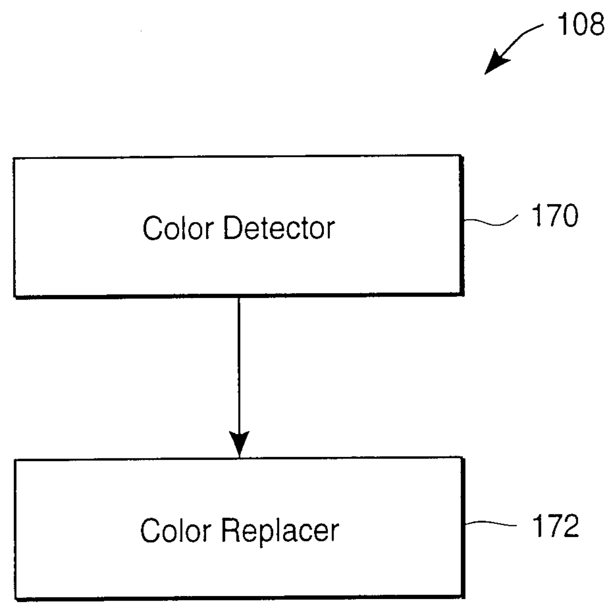

FIG. 1C

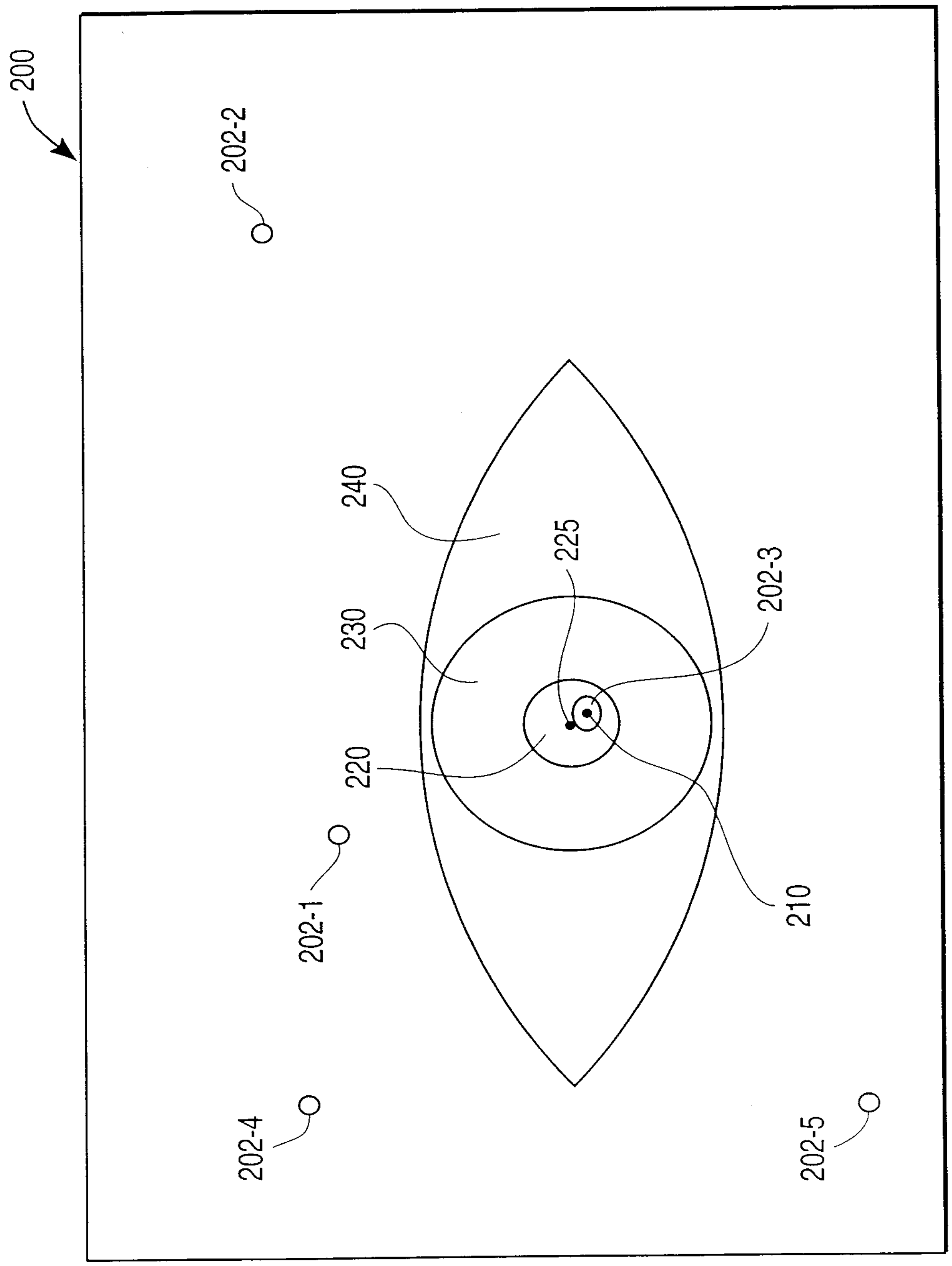

FIG. 2

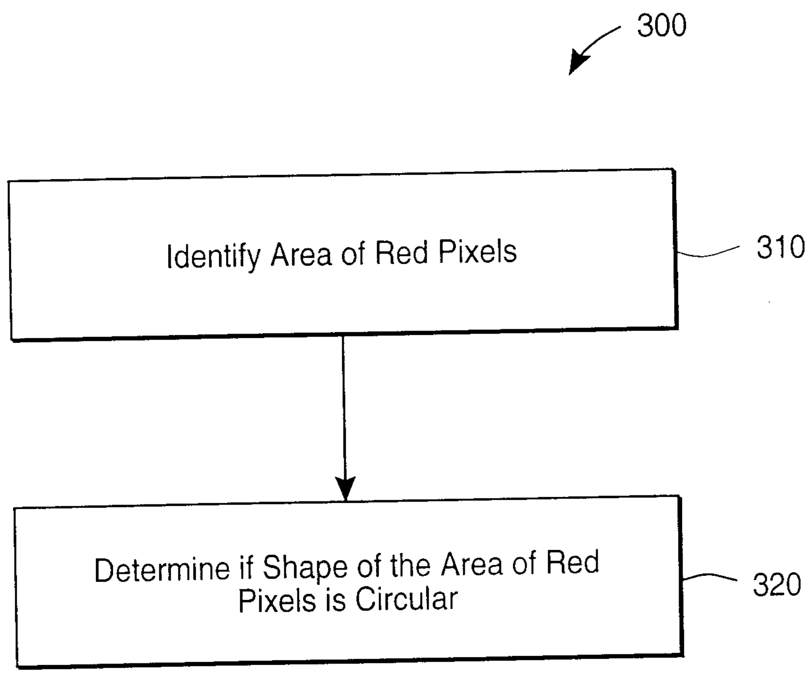
300
Identify Area of Red Pixels
310
Determine if Shape of the Area of Red Pixels is Circular
320

FIG. 3A

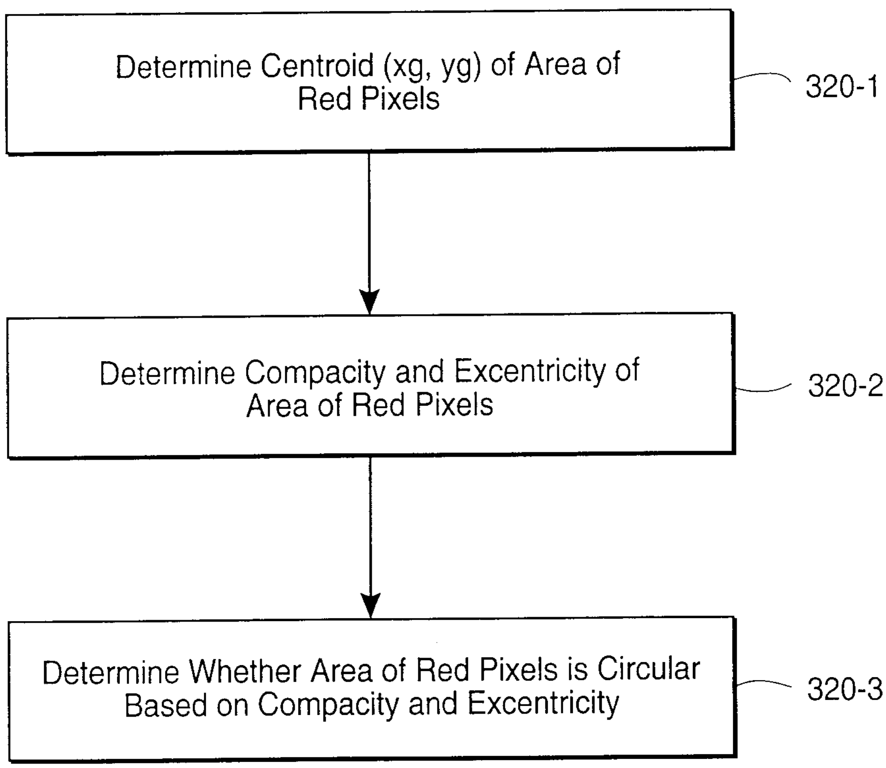
Determine Centroid (xg, yg) of Area of Red Pixels
320-1
Determine Compacity and Excentricity of Area of Red Pixels
320-2
Determine Whether Area of Red Pixels is Circular Based on Compacity and Excentricity
320-3

FIG. 3B

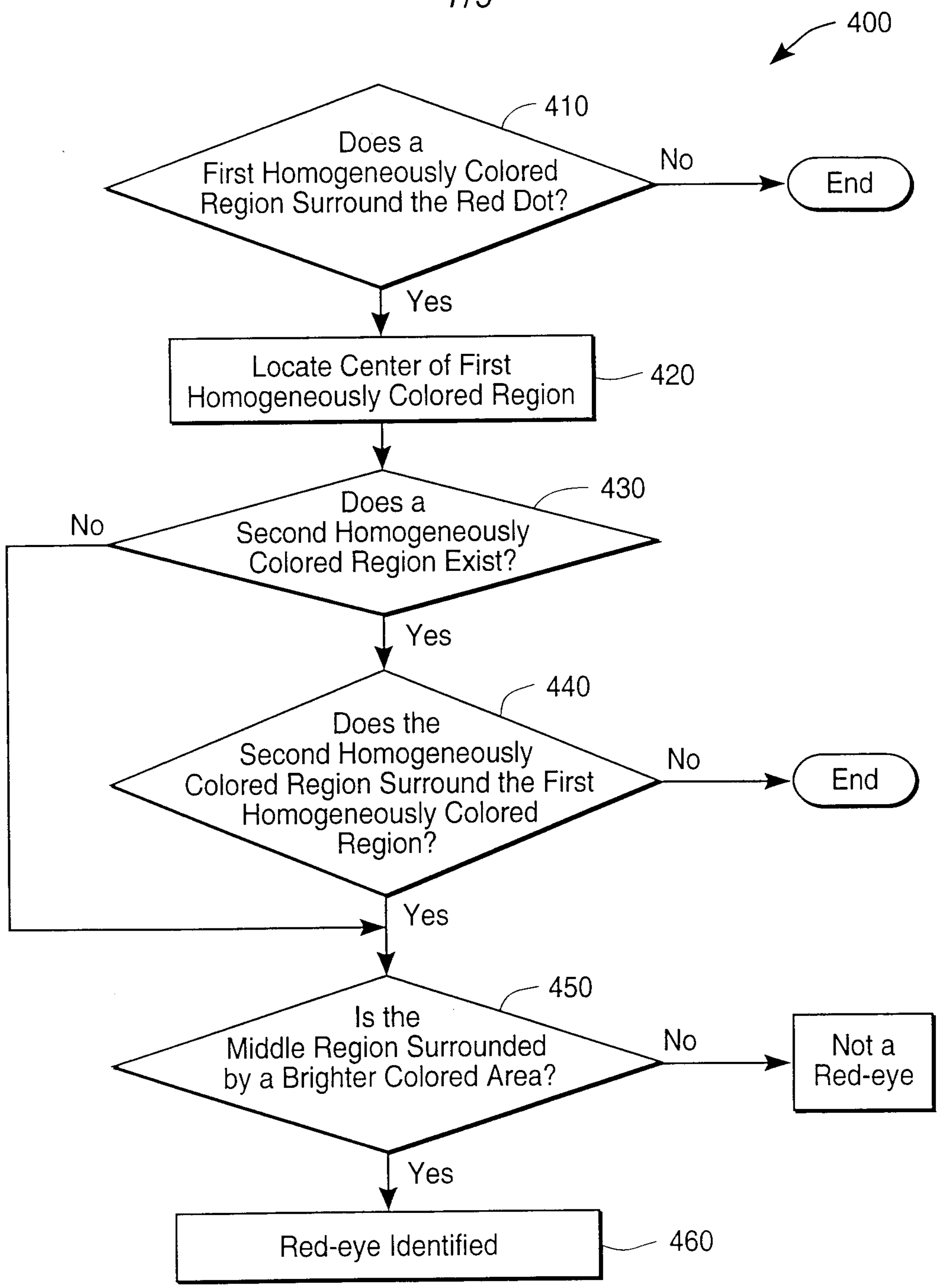
400
410
Does a First Homogeneously Colored Region Surround the Red Dot?
No
End
Yes
Locate Center of First Homogeneously Colored Region
420
430
Does a Second Homogeneously Colored Region Exist?
No
Yes
440
Does the Second Homogeneously Colored Region Surround the First Homogeneously Colored Region?
No
End
Yes
450
Is the Middle Region Surrounded by a Brighter Colored Area?
No
Not a Red-eye
Yes
Red-eye Identified
460

FIG. 4

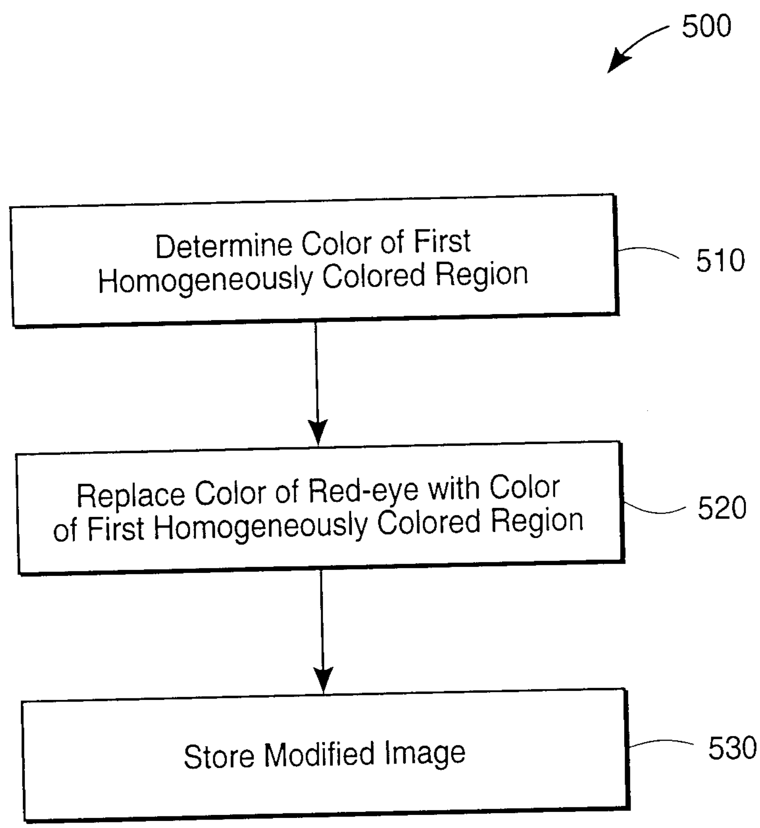
500
Determine Color of First Homogeneously Colored Region
510
Replace Color of Red-eye with Color of First Homogeneously Colored Region
520
Store Modified Image
530

FIG. 5

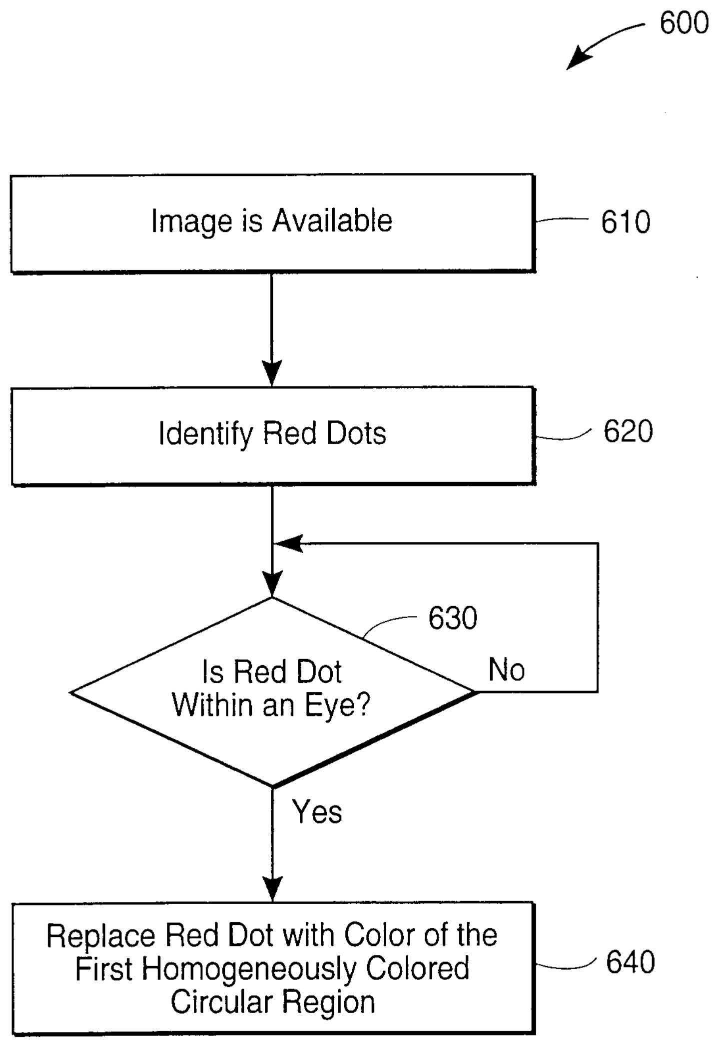
600
Image is Available
610
Identify Red Dots
620
630
Is Red Dot Within an Eye?
No
Yes
Replace Red Dot with Color of the First Homogeneously Colored Circular Region
640

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG 00/00040

CLASSIFICATION OF SUBJECT MATTER

IPC^7: G03B 15/00; G07T 7/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC^7: G03B, G06T, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

epodoc, paj, wpi

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0911759 A2 (Hewlett-Packard) 28 April 1999 (28.04.99) abstract, claims 1,2,7,8.	1,14
A	US 6009209 A (Microsoft) 28 December 1999 (28.12.99) claims 1,2,11,12,13,22.	1-19
A	JP 11 284874 A (Hewlett-Packard) 15 October 1999 (15.10.99) abstract.	1-19
A	JP 10 341352 A (Konica) 22 December 1998 (22.12.98) abstract.	1,10,14,19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

„A" document defining the general state of the art which is not considered to be of particular relevance

„E" earlier application or patent but published on or after the international filing date

„L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

„O" document referring to an oral disclosure, use, exhibition or other means

„P" document published prior to the international filing date but later than the priority date claimed

„T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

„X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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